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(54) ARC SPINNER INTERRUPTER WITH CHROMIUM COPPER ARCING  
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## ARC SPINNER INTERRUPTER WITH ARC RUNNER

### ABSTRACT OF THE DISCLOSURE

An arc spinner interrupter with first and second electrical terminal means and a movable contact movable along an axis between an engaged and a disengaged position. An annular arc runner means disposed in a plane perpendicular to the direction of movement of the movable contact and having an axis which is coaxial with the axis of movement of the movable contact. The annular arc runner means is electrically engaged by the movable contact when the movable contact is in its engaged position. The arc runner means defines a path for the annular rotation of the arc root of an arc which is drawn between the arc runner means and the movable contact when the movable contact moves to its disengaged position. A dielectric gas filling the space which will be occupied by an arc drawn between the movable contact and the arc runner means. A magnetic field generating means produces a magnetic field in the space in which the field has at least one component which is perpendicular to the axis of the arc runner means, to produce a Lorentz force which rotates the arc relative to the dielectric gas. The first circuit means connects the movable contact to the first terminal means and the second circuit means connects the annular arc runner means to the second terminal means with at least one of said arc runner means and the movable contact being made at least partly of a chromium copper alloy to improve interruption capability.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An arc spinner interrupter comprising, in combination: first and second electrical terminal means; a movable contact movable along an axis, and between an engaged and a disengaged position; annular arc runner means having at least a portion thereof disposed in a plane perpendicular to the direction of movement of said movable contact and having an axis which is coaxial with said axis of movement of said movable contact; said annular arc runner means being electrically engaged by said movable contact when said movable contact is in its said engaged position; said arc runner means defining a path for the annular rotation of the arc root of an arc which is drawn between said arc runner means and said movable contact when said movable contact moves to its said disengaged position; dielectric gas filling the space which will be occupied by an arc drawn between said movable contact and said arc runner means; magnetic field generating means for producing a magnetic field in said space, which field has at least one component which is perpendicular to said axis of said arc runner means, thereby to produce a Lorentz force which rotates said arc relative to said dielectric gas; first circuit means connecting said movable contact to said first terminal means; and second circuit means connecting said annular arc runner means to said second terminal means; at least one of said arc runner means and said movable contact being made at least partly of a chromium copper alloy to improve interruption capability.

2. The device of claim 1 which further includes housing means for enclosing said movable contact, said arc runner means, and said dielectric gas; said first and second terminal means being accessible externally of said housing means.

3. The device of claim 1 wherein said magnetic field generating means includes a winding which is coaxial with said arc runner means and which is closely coupled thereto and which is in series therewith, whereby a magnetic field is produced by the current through said winding, and by the current which is induced to circulate around said arc runner means.

4. The device of claim 3 wherein said winding is a spiral wound winding of flat conductive material which is wound in a plane which is parallel to the plane of said arc runner means.

5. The device of claim 1 wherein said alloy is about 0.9% chromium by weight.



This invention relates to circuit interrupters, and more specifically relates to a novel arc runner construction for the arc runner of an arc spinner type of circuit interrupter.

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This application is related to copending Canadian applications Serial No. 318,651, filed December 27, 1978 in the names of Lorne D. McConnell, Gerald A. Votta and Donald E. Weston, entitled MOVING CONTACT FOR RADIAL BLOW-  
10 IN EFFECT FOR ARC SPINNER INTERRUPTER; Serial No. 318,652, filed December 27, 1978 in the name of Robert Kirkland Smith, entitled EXTERIOR CONNECTED ARC RUNNER FOR ARC SPINNER INTERRUPTER; both of which are assigned to the assignee of the present invention. This application is a divisional  
15 application of copending application No. 326,707 filed May 1, 1979.

Arc spinner type interrupters are known in the art and are typically shown in U.S. Patent 4,052,577, in the name  
20 of Gerald A. Votta, as well as U.S. Patent 4,052,576, in the name of Robert Kirkland Smith.

In these devices, a flat conductive ring, hereinafter called the arc runner, is provided which is disposed in a  
25 plane perpendicular to the axis of the interrupter and perpendicular to the flow of arc current.

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during circuit interruption. This arc runner is then electrically connected in series with a coil to which it is closely coupled. A movable contact is then arranged to make annular contact engagement and disengagement with  
5 a cooperating annular surface of the arc runner facing away from the coil. When the contact opens, an arc is drawn from the arc runner to the movable contact and the arc current flows through the coil. This then induces a circulating current in the arc runner, which is a shorted  
10 turn, and both the arc runner and coil then produce a resultant magnetic field in the region of the arc.

The magnetic field component from the arc runner circulating current is displaced in phase from that of the coil so that a fairly substantial field is  
15 present just before a current zero interval. The effect of the arc current in the magnetic field produced by the arc runner and coil is such that a Lorentz force is established which tends to rotate the arc around the arc  
runner. This rotational movement of the arc is through a  
20 relatively static dielectric gas which fills the arc space and thereby tends to deionize and cool the arc so that the arc can be interrupted at the first current zero.

A problem exists in such interrupters when low currents (below about 3000 amperes) with high transient  
25 recovery voltage (TRV) frequencies of about 20 k Hz. Thus, in this low current range, the arc is interrupted in a plain break mode and not in a rotating arc mode.

Standard arc-resistant materials, such as copper tungsten alloys, perform well in the plain break mode, but they do not work well in the rotating arc mode. Standard electrolytic copper performs very well in the rotating mode, but does not  
5 work well in the plain bread condition. Therefore, in the past, it has been necessary to provide auxiliary means, such as a puffer assist, to allow the use of electrolytic copper for the rotating arc mode while giving the interrupter low current, high frequency TRV interruption capability.

10 In copending application No. 326,707 there is disclosed and claimed a circuit interrupter comprising a stationary contact assembly; a movable contact assembly; a dielectric gas filled housing containing said stationary  
15 and movable contact assemblies; and stationary contact assembly including an arc runner contact and an electrical coil and circuit connection means for connecting said electrical coil in series with said arc runner contact; said arc  
20 runner contact containing, as at least a portion thereof, a generally flat conductive disk having an axis which is coaxial with the axis of said coil; said coil being disposed adjacent one surface of said arc runner contact and being  
in a plane parallel to the plane of said arc runner contact and being closely magnetically coupled to said arc runner  
25 contact; said movable contact assembly including a generally cylindrical arcing contact which is coaxial with said arc runner contact, and which is movable into and out of contact with the surface of said arc runner contact which is  
opposite to said one surface; at least one of said arc  
30 runner contact and said movable arcing contact consisting of an alloy of chromium copper to improve interruption capability.

According to the present invention there is provided  
35 an arc spinner interrupter comprising, in combination;

first and second electrical terminal means; a movable contact movable along an axis, and between an engaged and a disengaged position; annular arc runner means having at least a portion thereof disposed in a plane perpendicular to the direction of movement of said movable contact and having an axis which is coaxial with said axis of movement of said movable contact; said annular arc runner means being electrically engaged by said movable contact when said movable contact is in its said engaged position; said arc runner means defining a path for the annular rotation of the arc root of an arc which is drawn between said arc runner means and said movable contact when said movable contact moves to its said disengaged position; dielectric gas filling the space which will be occupied by an arc drawn between said movable contact and said arc runner means; magnetic field generating means for producing a magnetic field in said space, which field has at least one component which is perpendicular to said axis of said arc runner means, thereby to produce a Lorentz force which rotates said arc relative to said dielectric gas; first circuit means connecting said movable contact to said first terminal means; and second circuit means connecting said annular arc runner means to said second terminal means; at least one of said arc runner means and said movable contact being made at least partly of a chromium copper alloy to improve interruption capability.

Thus in accordance with the invention, the arc runner is made of a chromium copper alloy having about 0.9% chromium by weight. It has been found that this material has relatively high conductivity relative to copper (about 85% of the conductivity of copper), and that it also has relatively low arc erosion and good transient recovery voltage withstand capability. Thus, the arc runner can be used for interruption in both plain break and rotating arc modes, without need for auxiliary means to assist interruption at low current.



BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a side elevational view of a circuit breaker which could incorporate the concept of the present invention.

5                Figure 2 is a front elevational view of Figure 1.

Figure 3 is a top view of Figures 1 and 2.

Figure 4 is a cross-sectional view taken along the axis of one of the three interrupters of Figures 1, 2 and 3 and illustrates an interrupter with a center-fed arc runner and shows the interrupter open above the center  
10                axis and closed below the center axis.

Figure 4a is an electrical circuit diagram of the structure shown in Figure 4.

Figure 4b is an enlarged cross-sectional diagram  
15                of the coil assembly of Figure 4.

Figure 5 is a perspective view of the stationary contact and arc runner shown in Figure 4.

Figure 6 is a perspective view of the movable contact assembly of Figure 4.

20                Figure 7 is a cross-sectional view of Figure 4 taken across the section line 7-7 in Figure 4.

Figure 8 is a cross-sectional view of Figure 4 taken across the section line 8-8 in Figure 4.

Figure 9 is an end view of the right-hand end  
25                of Figure 4.

Figure 10 is an enlarged view of the stationary contact and arc runner of Figure 4 modified so that current to the arc runner is connected at its outer diameter.

5           Figure 11 schematically illustrates the arc current between the arc runner and the movable arcing contact for different conditions of current feed to the inside and outside of the arc runner and further shows different conditions of current flow, for inside feed and  
10 outside feed to the arcing contact.

Figure 12 shows low current test results of apparatus of the type shown in Figure 10 using a chromium copper alloy arc runner, as compared to one using a copper arc runner.

15           Figure 13 shows low current test results comparing the use of copper, copper tungsten, and chromium copper materials at high TRV frequency.

#### DETAILED DESCRIPTION OF THE DRAWINGS

Figures 1 to 3 illustrate a typical circuit  
20 breaker which uses circuit interrupters of the type constructed in accordance with the present invention. Referring to Figures 1 to 3, the circuit breaker is mounted on a steel support frame 20 and is shown as a three-phase circuit breaker containing phases 21, 22  
25 and 23. Each of phases 21, 22 and 23 consist of

identical interrupters, one of which will be described more fully hereinafter, contained in respective aluminum tanks 24, 25 and 26, which have terminal bushings 27-28, 29-30 and 31-32, respectively. Each of housings 24, 25 and 26 are capped at their right-hand end in Figure 1 and communicate with an operating mechanism housing 35, which may include a jack-shaft linkage which is coupled to the interrupters within each of housings 24, 25 and 26. The operating mechanism is operable to simultaneously open and close the three interrupters. Any suitable spring closing mechanism or the like, shown as the spring closing mechanism 36, can be used to apply the input energy for the jack-shaft linkage in housing 35. Thus, an operating link 37 extending from the spring mechanism 36 is connected to an operating link 38 (Figure 1) which in turn rotates shaft 39 which is coupled to the interrupters of each phase as will be more fully described hereinafter.

It is necessary that the housing 35 be sealed since it will be filled with a suitable dielectric gas such as sulfur hexafluoride and permits communication of the insulating gas between the interiors of all housings 24, 25 and 26.

The circuit breaker described above is suitable for use in connection with a 15kV/25kA three-phase outdoor circuit breaker and can have a total height of about 82 inches with frame and a total width in Figure 1 of about 38 inches.

The interior of the interrupter for each phase is shown in Figure 4 for the case of phase 23 encased by housing 26. Housing 26 may be of steel or of any other desired material and contains two openings 40 and 41 for receiving the bushings 31 and 32. Thus, openings 40 and 41 have short tubes 42 and 43, respectively, welded thereto, which tubes receive suitable terminal bushings 31 and 32 in any desired manner.

The terminal bushings 31 and 32 then have central conductors 44 and 45, respectively, which are terminated with jaw type contacts 46 and 47, respectively, which receive movable contact assembly 48 and stationary contact assembly 49, respectively, as will be later described.

The right-hand end of housing 26 is capped by an end assembly including seal ring 50 (Figure 4) which contains a sealing gasket 51 (Figure 4), an aluminum support plate 52 (Figures 4 and 5) and an end cap plate 53 which may be of steel. Ring 50 is welded to the right-hand end of tube 26 and provides a bolt-hole ring. The aluminum disk 52 is held in the position shown by the plate 53 when the plate is bolted to the ring 50 as by the bolts 54 and 55 shown in Figure 4. Note that plate 53 is shown in both Figure 4 and Figure 9 and, when the plate 53 is bolted up against the ring 50, it forms a leak-proof seal against the sealing ring 51.

The opposite end of tube 26 has a bolt ring 60 welded thereto which has a three-lobe type opening as best shown in Figure 7. A short tube section 61 is then provided with a sealing ring 62 connected to its end which receives a sealing gasket 63. The outer diameter of ring 62 contains a bolt ring circle having bolt openings in alignment with the bolt openings in member 60 so that bolts, such as bolts 65 and 66 in Figures 4 and 7, can secure together housing sections 26 and 61 with a good gas-tight seal being formed by the seal 63.

The left-hand of section 61 is then welded into an opening in the tank 35 as shown. Thus, the interior of tube 26 and of the various elements with which it communicates are sealed from the external atmosphere and the interior of tube 26 is filled with sulfur hexafluoride at a pressure of about 3 atmospheres absolute. Note, however, that any desired pressure could be used and that any dielectric gas other than sulfur hexafluoride or combinations of dielectric gases as desired could be used in place of sulfur hexafluoride.

The movable contact assembly 48 is best shown in Figures 4 and 6. The movable contact assembly is connected to the operating crank 38 of Figure 4 which is driven by the operating mechanism through a connecting link 70 which is pivotally connected to the end of elongated axially movable conductive member 71. Movable

member 71 is a conductive elongated hollow rod having a closed end at its left where the closed end portion at its left-hand end is provided with a plurality of vents such as vents 72 and 73 which, as will be described hereinafter, permit flow of gas and arc plasma through the movable contact and through these vents during an interruption operation.

Movable member 71 is guided for motion by a stationary conductive support member 74 which contains a sliding contact member 75 (Figure 4) which maintains electrical sliding contact with the conductive tube 71. A suitable insulation layer 76 (Figure 4) can be fixed to member 74 to provide relatively low friction guiding of the movable member 71. Contact 75 is then held in place by a suitable conductive backup plate, such as plate 77, which is held in place by suitable screws.

Conductive stationary support member 74 is also provided with an upwardly extending conductive tab 78 which is fixed to member 74 by bolts 79 and 80. (Figure 6) and the tab 78 engages the jaw contact 46 when the device is assembled. The support member 74 is then fixed to the ring 60 by three insulation support members 81 and 82 (Figure 6) and 83 (Figure 4) which may be molded epoxy members. The right-hand end of each of these members is bolted to member 74 as by bolts 85, 86 and 87, respectively, and their opposite ends are bolted to member 60 as by the bolt 88 shown in Figure 4

for the case of insulation support member 83. Similar bolts connect the other insulation supports to the member 60 but are not shown in the drawings. Thus, the movable contact assembly is insulatably supported from the housing 26.

The main movable contact element then consists of a bulbous movable contact member 90 which is terminated by a plurality of segmented contact fingers 91.

Member 90 defines an outwardly looping current path from the centrally located conductive member 71 and may be suitably electrically connected to the end of member 71 as by a threaded connection to the intermediate conductive ring 92 which is, itself, threaded to the end of member 71. Intermediate member 92 also serves as a seat for compression spring 93 which is pressed against the inner diameter of the interior sliding arcing contact member 95. Arcing contact 95 has a central opening 96 at its outer diameter and receives a suitable nonconductive ring 97 which enables member 95 to slide relatively easily with the fingers 91. Note that the ends of fingers 91 bend inwardly to define a shoulder 99 which engages the shoulder 100 when the fingers move to the left while the interrupter is opening.

The stationary contact structure 49 is best shown in Figures 4 and 8. Stationary contact structure 49 has a main support housing section 110 which may be of aluminum and has a tab 111 extending therefrom and

bolted thereto as by the bolts 112 and 113. Tab 111 is then received by the jaw contact 47 to make connection between the stationary contact assembly and the terminal bushing 32.

5           Support member 110 then has three epoxy support members 114, 115 and 116 bolted thereto as by bolts such as the bolt 117 shown in Figure 4 for the case of member 114. The support members 114 to 116 are then in turn bolted to the aluminum disk 52 as by bolts such as bolt 118 shown in  
10       Figure 4 for the case of member 114. Thus, the entire stationary contact assembly is insulatably secured from the main support casing. 26.

15           Member 110 has an intermediate aluminum support member 120 (Figures 4 and 4b) bolted thereto as by bolts such as bolt 121 shown in Figure 4 and a main stationary contact sleeve 122 is threadably connected or otherwise suitably connected to the member 120. The end of member 122 may have a contact ring insert 123 which may be of a  
20       material which can resist arc erosion, such as copper-tungsten or the like for receiving the inner ends of contact fingers 91 of the movable contact when the interrupter is closed, and for forming a good solid low-resistance current conduction path between contact assemblies  
25       48 and 49. Note that fingers 91 are outwardly and elastically pressed when they engage member 122 to provide high pressure contact. The end of the contact sleeve 122 is then terminated by a Teflon (a trade mark) ring 130 which generally covers the outer end of the stationary contact  
30       assembly and has the generally trapezoidal cross-sectional shape shown. Ring 130 can be secured in place relative to sleeve 122 as by threading or the like.

35           The stationary contact assembly shown in Figure 4 further contains a copper coil support member 140 (see Figure 4b) which consists of a central core section 141



which has a central opening 142 therein, and two integral spaced flanges 143 and 143a extending from core 141. Flange 143 acts as an arc runner and is a generally washer shaped conductive plate which may be of a chromium copper material. Rear flange 143a is preferably slotted to discourage circulating current. Coil support 140 should be sufficiently strong to withstand forces of repulsion which tend to repel the coil winding and the arc runner 143. A Teflon (a trade mark) or other insulation material nut 145 covers the interior surface of arc runner 143 and define an annular shaped exposed contact area for arc runner 143.

Insulation members 148, 149 and 149a are disposed between copper coil support member 140 and sleeve 122 to prevent their accidental contact. The space between arc runner 143 and flange 143a receives a winding 150 which is a spiral winding, for example, consisting of eleven concentric flat turns which are insulated from one another. If desired, the turns of winding 150 can be made of other cross-section shapes,

and could, for example, be square in cross-section. The interiormost coil of winding 150 is electrically connected to the central hub 141 while the outermost coil of winding 150 is electrically connected to member 120 by the conductive strap 151. Thus, an electrical connection is formed from terminal 111 (Figure 4) through member 110, member 120, conductive strap 151, winding 150, and to the hub 141 of member 140. In the embodiment of Figure 4, current is connected to arc runner 143 at its interior. Current is introduced into hub 141 from coil 140, and is then connected directly to the interior diameter of arc runner 143.

There can be an outside feed of current to arc runner 143, whereby the outer diameter of flange 143a is connected to the outer diameter of the arc runner 143. The current path for either inside or outside feed to arc runner 143 is schematically shown in Figure 4a. Suitable insulation layers are provided as necessary to define the inside or outside-fed connection to the arc runner 143. Figure 10, which will be later described, shows the outside feed in detail.

In the construction described to this point, it can be seen that the assembly of the interrupter is simplified by the removable connection between the movable and stationary contact assemblies 48 and 49 with the jaw contacts 46 and 47 for the terminal bushings 31 and 32.

The current path through the interrupter, when the interrupters are in the closed position shown below the center line in Figure 4, is as follows:

Current enters terminal 31 and flows through  
5 jaw contact 46 and tab 48 and is then connected to the  
conductive member 71 through the sliding contact 75.  
Current then flows axially outwardly into movable contact  
member 90 and then through the contact fingers 91 and  
into contacts 123 and 122. Current then continues to  
10 flow into member 120 and member 110 and then through the  
tab 111 into the jaw contact 47 and then out of the  
bushing 32.

In order to open the interrupter contacts, the  
operating mechanism causes link 38 to rotate counter-  
15 clockwise in Figure 4, thereby moving conductive member  
71 to the left. During the initial opening motion, the  
contact fingers 91 move to the left in Figure 4 so that  
the main contacts open and electrical current flow is  
commutated from the main contact into the arcing contact  
20 95, which is still engaged with the arc runner 143, coil  
150, and then through members 120 and 110 to tab 111.

Contact 95 may be of a copper chromium  
material or some other material well suited to withstand  
arcing duty. The arcing contact 95 is initially strongly  
25 held against the arc runner 143 under the influence of  
the spring 93. Once the movable contact fingers 91 have  
moved sufficiently far to the left, however, shoulder 99

of the fingers 91 pick up shoulder 100 of arcing contact 95 and, for the first time, the arcing contact 95 begins to move to the left, and out of contact with arc runner 143. An arc is then drawn between the arc runner surface 143 to the arcing contact 95 which arc current flows in series with the coil 150.

The current through coil 150 then sets up a magnetic field which has a component extending perpendicularly through the arc current flowing between arc runner 143 and contact 95. At the same time, since coil 150 is very closely coupled to the arc runner 143 (which is a short-circuited turn), a circulating current is induced in the arc runner 143. This circulating current is phase-shifted relative to the arc current and the current in coil 150. The current in the coil 150 and the circulating current in runner 143 produce a magnetic field in the arc space, which field has a component which is perpendicular to the arc current. The arc current and the magnetic field interact to produce a Lorentz force on the arc, thereby causing the arc to rotate rapidly around the axis of runner 143 and contact 95. Consequently, the arc spins rapidly through the relatively stationary dielectric gas, thereby to cool and deionize the arc so that it will extinguish at current zero.

Improved operation is obtained when current applied to the arc runner 143 is applied at its outer diameter,

so that a blow-in magnetic force is applied to the arc current, causing it to bend toward the axis of rotation of the interrupter.

5 The effect of the outside feed to the arc runner can be best understood by a consideration of Figures 10 and 11. Figure 11 schematically illustrates a few of the disclosed stationary contact assembly components.

10 Figure 10 shows the movable contact assembly 48 of Figure 4 along with a stationary contact assembly 49 which is modified for outside feed of current. Thus, in Figure 10, arc runner 143 is modified to have a cup shape, and has cylindrical wall 200 which extends coaxially over winding 150, and is threadably engaged to the outer periphery  
15 of flange 143a. Suitable insulation disks 201 and 202 and insulation cylinder 203 insulate coil 150 from cylindrical wall 200, runner 143 and flange 143a. Insulation sleeve 204 insulates contact sleeve 122 from the conductive wall 200.

20 Lead 151 is connected to the outermost coil of winding 150, and its innermost coil is connected to hub 141. The arc runner 143 is mechanically held closely coupled to coil 150 by steel bolt 205 which is sheathed with insulation, such as Teflon (a trade mark) cylinder 206 and Teflon (a  
25 trade mark) cap 207. Bolt 206 presses against plate 208 and insulation disk 209 as shown.

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Contact 122 in Figure 10 is threaded onto a conductive support 210 which, as in Figure 4, is suitably connected to member 110 and terminal bushing 32.

5 It should be noted that flange 143a is slotted as by slot 211 at one or more places on its periphery to avoid inducing a circulating current around flange 143a.

It will be clear from Figure 10 that the current path to arc runner 143 will follow the path of the arrows so that current will be connected to runner 10 143 around its full outer periphery. The effect of this outside feed of current is best understood from Figure 11 which schematically shows the arc runner 143 for different current feed conditions.

Figure 11 illustrates, by graduated arrows, 15 the magnetic flux density field B plotted across the pertinent regions of the area through which the arc between arc runner 143 and movable arcing contact 95 will travel. It will first be noted that the intensity of the magnetic field is greatest closest to the arc 20 runner 143. This is because the magnetic field B is produced by the circulating current in member 143 and also by the coil 150 which is disposed behind member 143. Thus, as the distance from coil 150 and member 143 increases, the field strength is reduced. At the same time, the 25 direction of the field vector varies over the area and is seen to be parallel to the interrupter central axis at regions along the central axis of member 143 and then

becomes closer to a perpendicular to the central axis of member 143, progressing radially outward from the axis.

The force which is exerted on the arc current drawn between arc runner 143 and movable arcing contact 5 95 is given by the vector cross product between the magnetic field B and the arc current. Thus, the closer to perpendicular the arc current is to the field vector, the greater will be the force tending to rotate the arc around the annular arc runner area.

10 If the current coming into arc runner 143 was straight and parallel to the central axis of runner 143 and in the absence of other disturbing forces, the arc current would take the path 159. Thus, the arc current would have a relatively large component perpendicular to 15 the various field vectors B to produce a rather high rotating force.

In the prior art, however, current is introduced to the arc runner 143 at the inside diameter of the arc runner. Thus, current has taken the path shown in 20 the solid line 160. Because of the bend in the current 160, a magnetic blow-off force will be exerted on the arc current, and the arc current will follow the outwardly bowed path 161. Because of this, the arc current in the high field region near the arc runner 143 will be more 25 parallel to the magnetic field vector B, so that a relatively low rotating force will be applied to the arc

current. Moreover, the arc 161 is outwardly blown, thus leading to the possible danger that the arc will transfer back to the main contact 122.

In accordance with the invention, the current feed is to the outside of the arc runner 143, as shown by the dotted-line path 162 in Figure 11. This then produces a blow-in or inward magnetic force on the arc, which is directed toward the axis of the arc runner 143, thereby to cause an inward bowing of the arcing current as shown by the arc current path 163. Note that the maximum inward bowing occurs closest to the arc runner 143, where the magnetic field B is the highest. Thus, in these very high intensity regions, the arc current is almost perpendicular to the magnetic field, thus producing extremely high rotating forces on the arc. Moreover, the arc 163 is blown away from the outside, thereby minimizing the danger of a flashover to the main contact members.

The opposite end of the arc root is on the arcing contact 95 as shown in Figure 11. An important aspect of the new device is that the current flow through the arcing contact 95 is radially outward, and over the dotted-line path 170 rather than the prior art type of inside feed to the arcing contact, shown in the solid line 171 path.

By causing the current path through the arcing contact to be an outside feeding path, current in the



moving contact 95 flows in the radially outward path from the arc root region and from the axis of the movable contact. Thus, there is an inward blow-off force applied to the arc root and to the arc in the region of the arcing contact 95. That is to say, the arc will tend to be moved inwardly toward the axis of the arcing contact 95 rather than outwardly, as would occur for an inside feed along the path 171 as in the prior art. This tends to maintain arc position on the most radially inward portion of the arcing contact so that arc position and arc length is maintained to minimize arc energy input to the gas and to prevent a flashover to the main contact.

It was previously pointed out, with respect to Figures 4 and 6, that the movable contact member 71 had openings such as openings 72 and 73 therein. Other openings are also distributed around the left-hand end of member 71. It has been found that these openings will assist in the removal or distribution of arc plasma which is produced during arcing. Thus, it has been found desirable to have some means for directing the arc plasma away from the arc zone during the interruption operation in order to move the arc plasma away from the main stationary contact.

By providing openings 72 and 73 or other similar openings along the length of conductor 71, the intense heat produced by the plasma in the region between the separating contact 95 and runner 143 will act as a

source to cause hot gases to move to the left along the axis of the tube 71 and then out through the openings of the tube. That is to say, the openings, such as openings 72 and 73, help define a flow channel along the center of the moving contact along which the hot gases can move in order to remove excess hot gases from the arcing zone.

This is extremely useful at higher current levels, where large amounts of hot gases are produced. It also has limited use in connection with low current interruption where a limited amount of hot gas is produced. However, in the case of low current interruption, it is useful to provide means for producing a negative pressure region within contact 71 to permit movement of at least a limited amount of gas away from the arc zone. This could be accomplished, for example, by blocking substantially the full interior of conductor 71 with a light insulation filler material and leaving a relatively small gas volume sufficient only to allow full movement of the arcing contact 95 to the right, relative to the movable contact when the contact opens. This limited movement will then cause a proportionally large increase in the volume to the left of contact 95 during opening, thereby to produce a negative pressure zone into which a limited amount of gas could flow under low current interruption conditions.

As previously indicated, and in accordance with the invention, arc runner 143 and other contact components are preferably made of a chromium copper alloy, preferably one having 0.9% chromium by weight.

5 This material has been found to perform well in the high current arc rotation mode of operation since its conductivity is 85% that of electrolytic copper. In accordance with the invention, this material was also found to perform about as well as copper tungsten in  
10 the low current, high TRV frequency mode. Note that copper tungsten cannot be used for the arc runner since its resistance is too high for proper operation in the arc rotation mode.

Figure 12 shows test results of an interrupter  
15 of the type shown in Figure 10 using a chromium copper material for arc runner 143 which had 0.9% by weight of chromium. In Figure 12, the shaded band 200 shows the boundary of successful operations (in the region to the left of band 200), with the interrupter using the chromium  
20 copper arc runner. By comparison, the dotted line 201 shows the boundary of successful operations using an electrolytic copper arc runner. Auxiliary interruption means are required for low current, high TRV frequency as seen by boundary 201. The dramatic improvement of  
25 boundary 200, using the novel chromium copper alloy arc runner, reduces or completely eliminates the need for such auxiliary equipment.

As pointed out previously, the chromium copper arc runner performs almost as well as copper in the arc rotation mode, and it performs almost as well as copper tungsten in the plain break mode. Figure 13 shows the results of an experiment comparing copper, copper tungsten and chromium copper at low current, high TRV frequency operation. In carrying out the experiment, a copper arc runner was used, facing a slotted fixed contact of the different compositions. A two inch gap was formed between the arc runner and contact and 15 kV R.M.S. was placed across the gap and an arc was artificially initiated. The coil in series with the arc runner had 7-1/2 turns.

The test results produced the success-failure boundaries 210, 211 and 212 for copper, chromium copper (0.9% chromium) and copper tungsten materials, respectively, for the slotted contact facing the arc runner. It can be seen that the chromium copper is almost as effective as the copper tungsten in the low current, high TRV frequency range of operation and in the plain break mode. It is also seen that the chromium copper is vastly superior to the copper (boundary 210) in the low current range.

Although a preferred embodiment of this invention has been described, many variations and modifications will now be apparent to those skilled in the

art, and it is preferred therefore that the instant invention be limited not by the specific disclosure herein but only by the appended claims.

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FIG. 1.

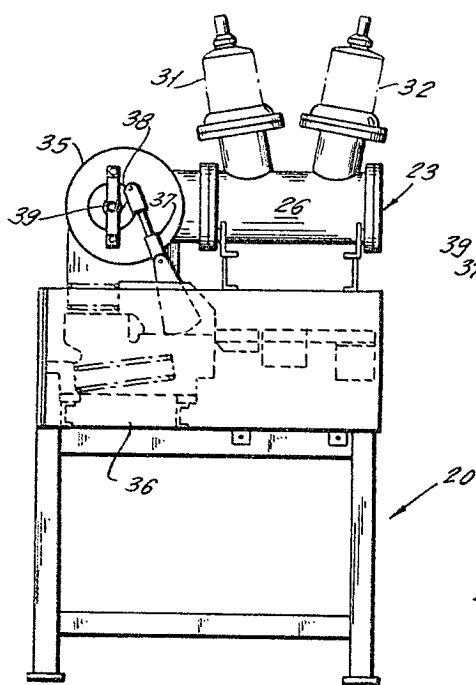


FIG. 2.

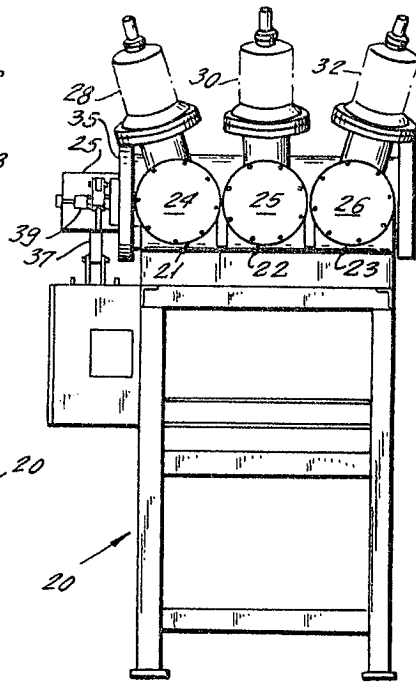


FIG. 4b.

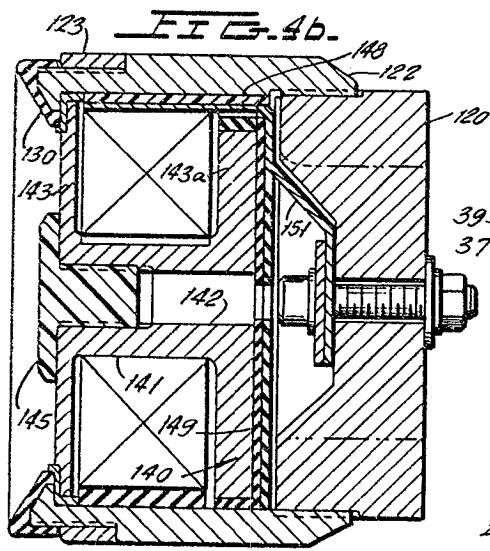
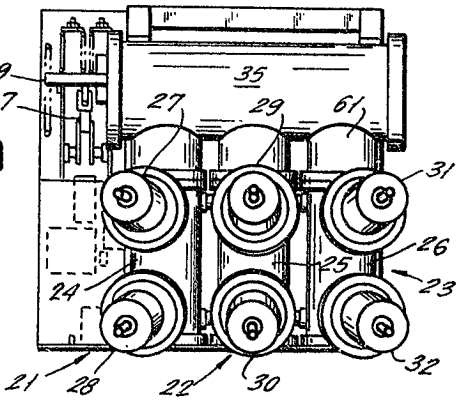
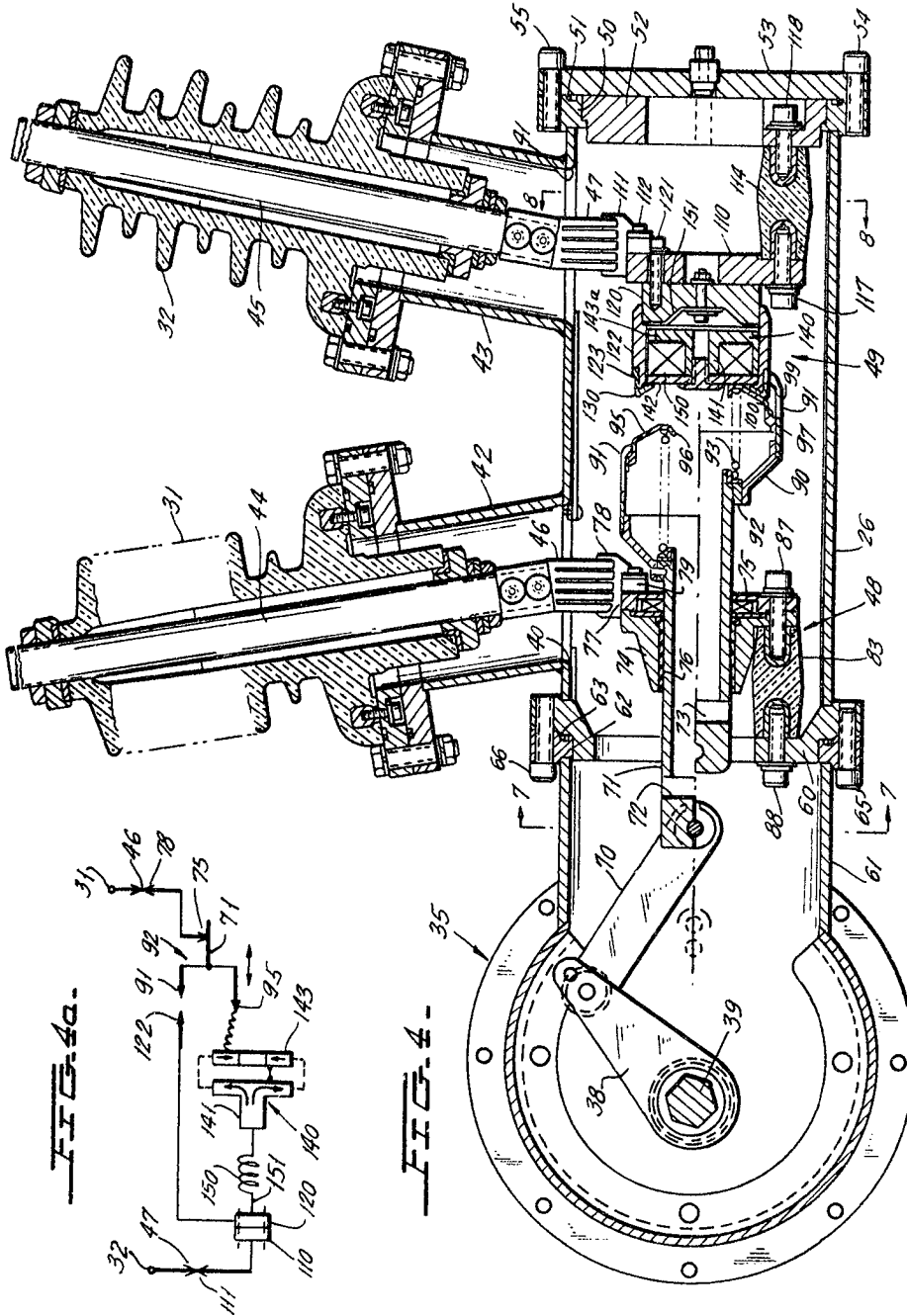


FIG. 3.



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FIG. 5.

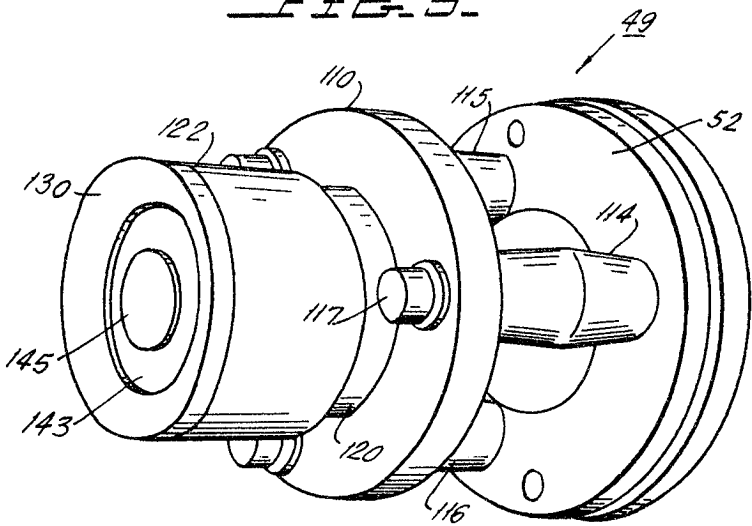


FIG. 6.

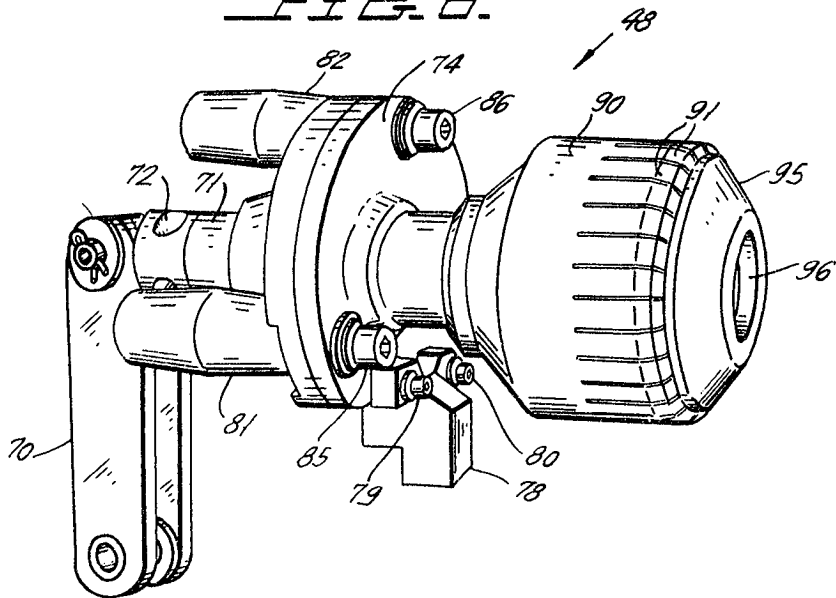




FIG. 7.

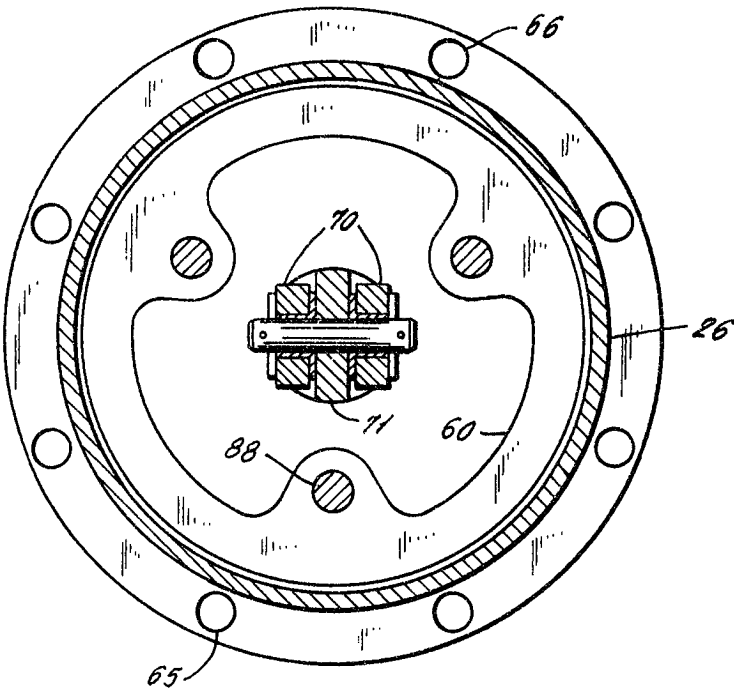
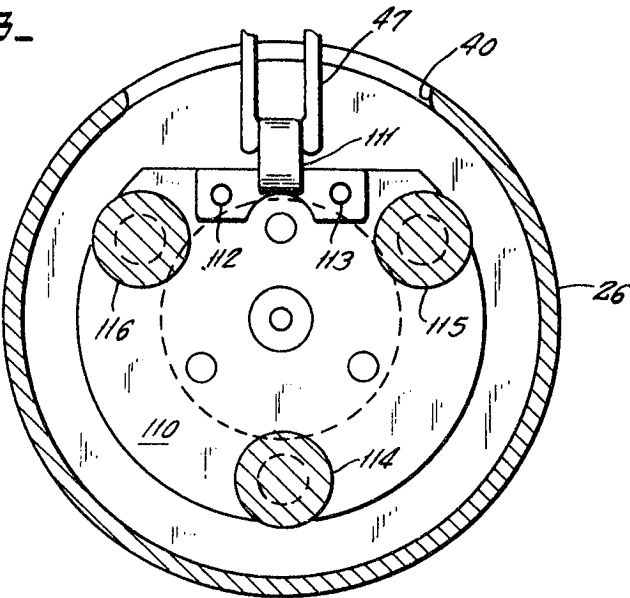


FIG. 8.



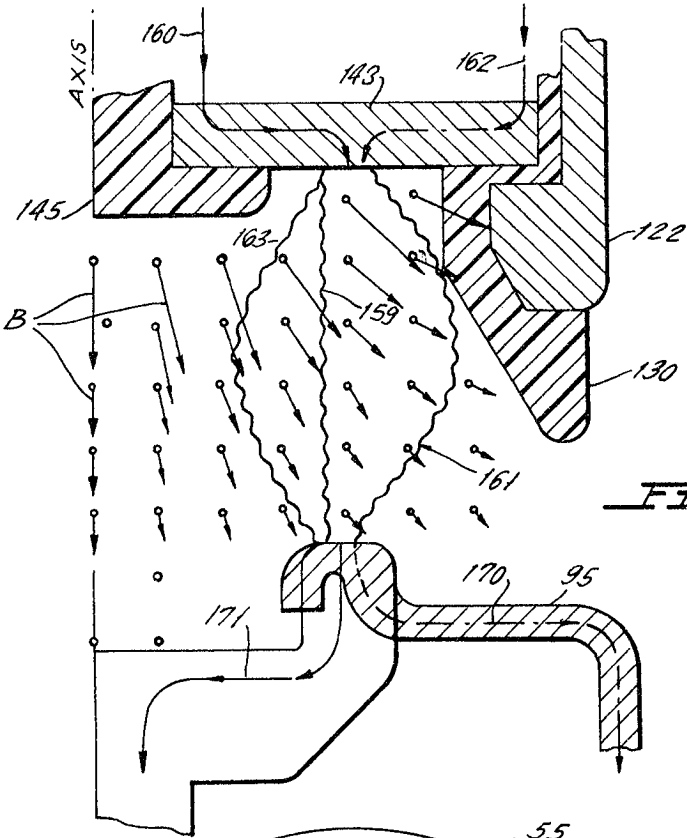


FIG. 11.

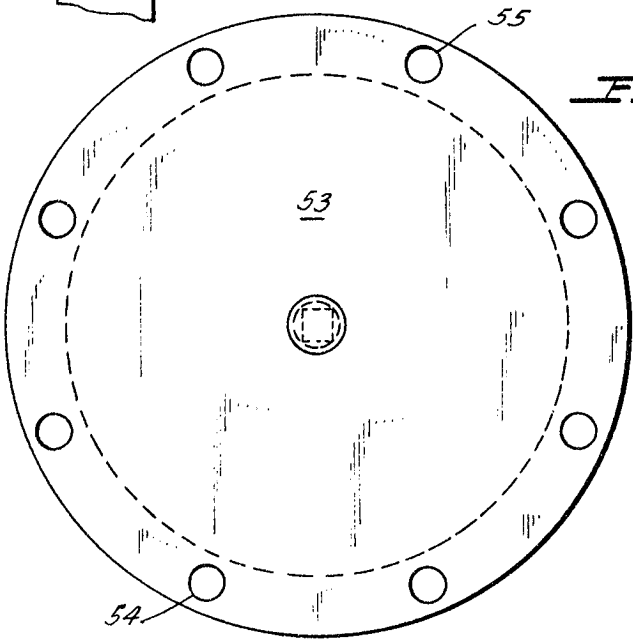
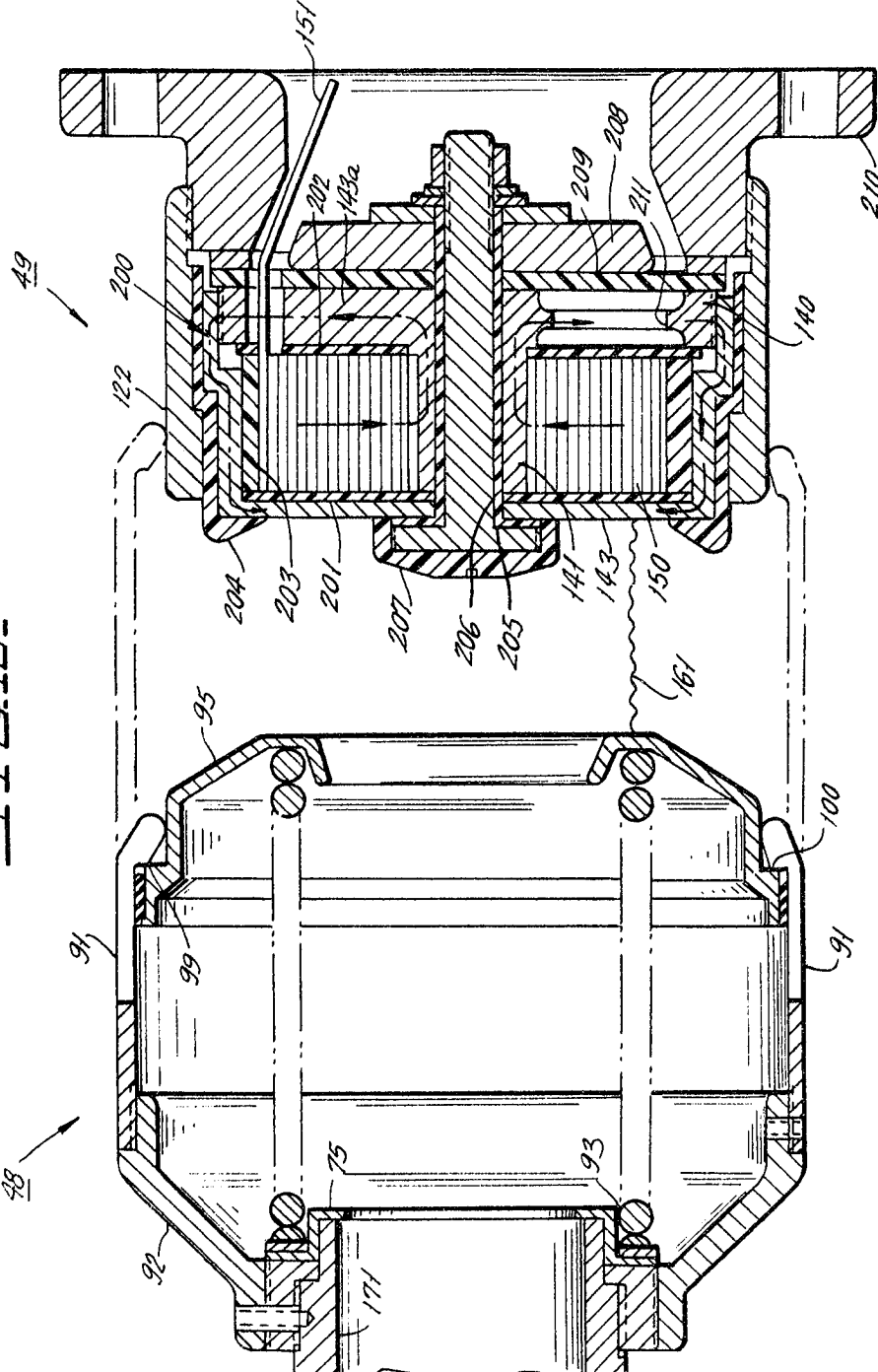


FIG. 9.

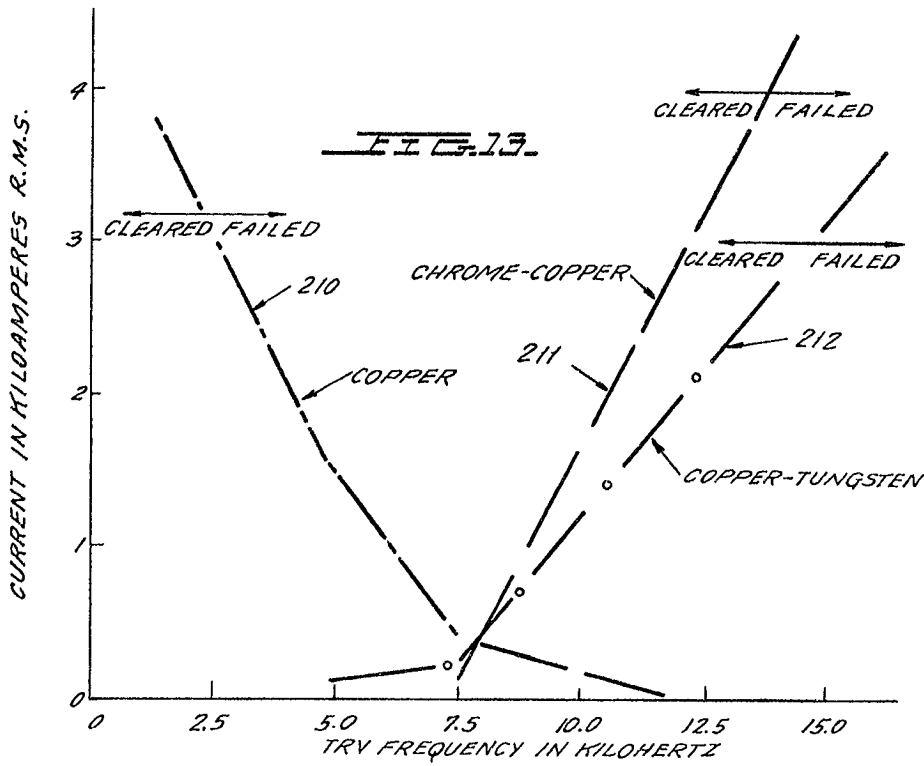
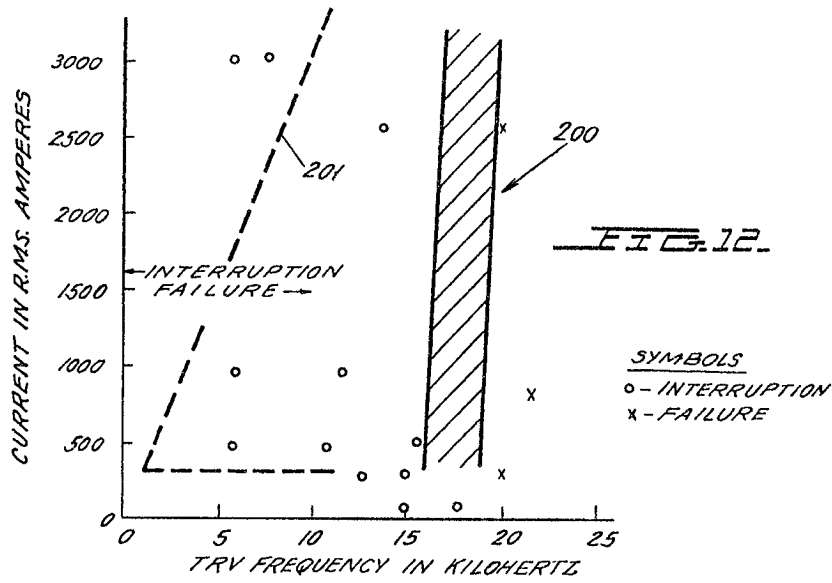
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FIG. 10.



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